



STATIONARY FUEL CELLS

Technology, Market Overview, Codes and Standards

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Distributed Energy Resources Road Show
Chicago Center for Green Technology

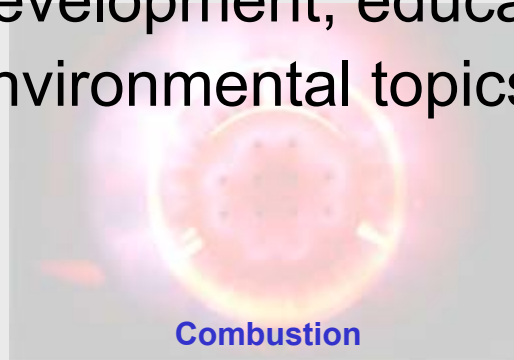
May 1, 2003

Gas Technology Institute

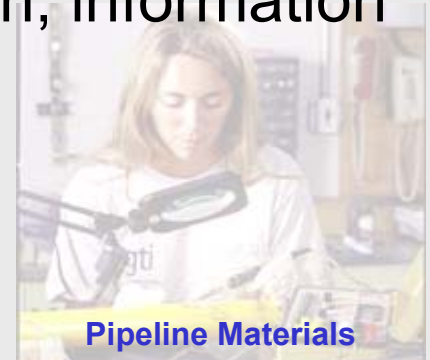
- > Independent, not-for-profit organization
- > Technology development, education, information
- > Energy and environmental topics



Fuel Cells

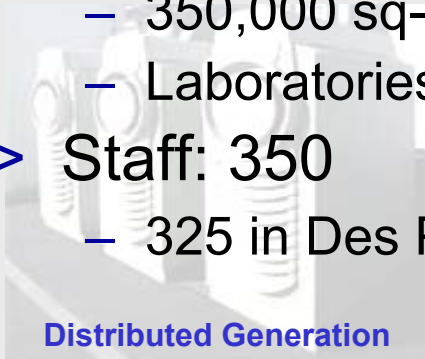


Combustion

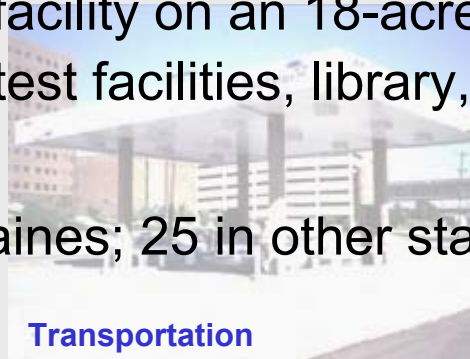


Pipeline Materials

- > Headquarters: Des Plaines, IL (Chicago area)
 - 350,000 sq-ft facility on an 18-acre campus
 - Laboratories, test facilities, library, classrooms, offices
- > Staff: 350
 - 325 in Des Plaines; 25 in other states, Canada



Distributed Generation



Transportation



Biotechnology

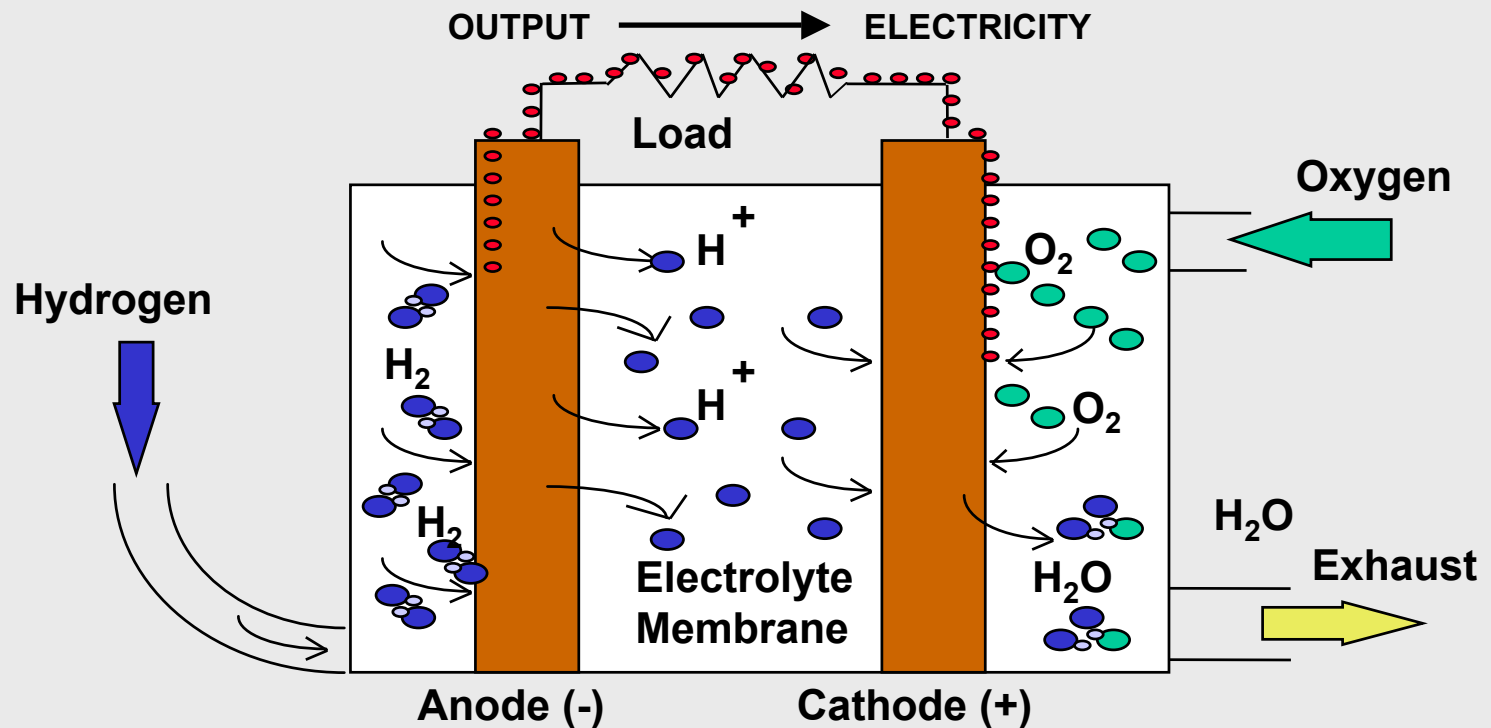
Presentation Overview

- > What are fuel cells?
 - How they work, types, attributes, benefits
- > Why do we care about fuel cells?
 - Where they will be used
- > Fuel cell codes and standards
 - What's in place and under development

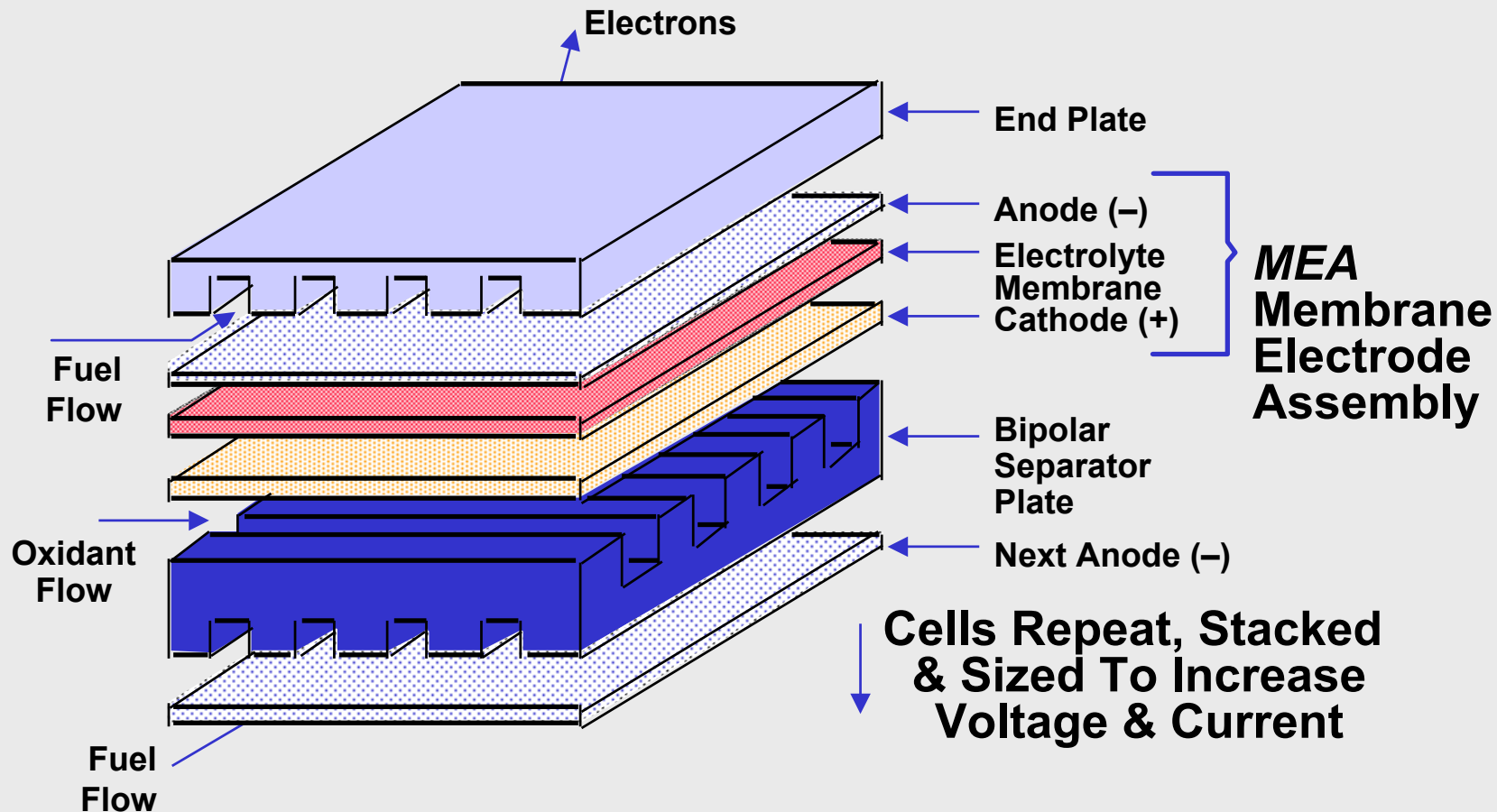
Basic Fuel Cell Operation

Basic
Reactions

Combining Hydrogen & Oxygen To Make Electricity & Water



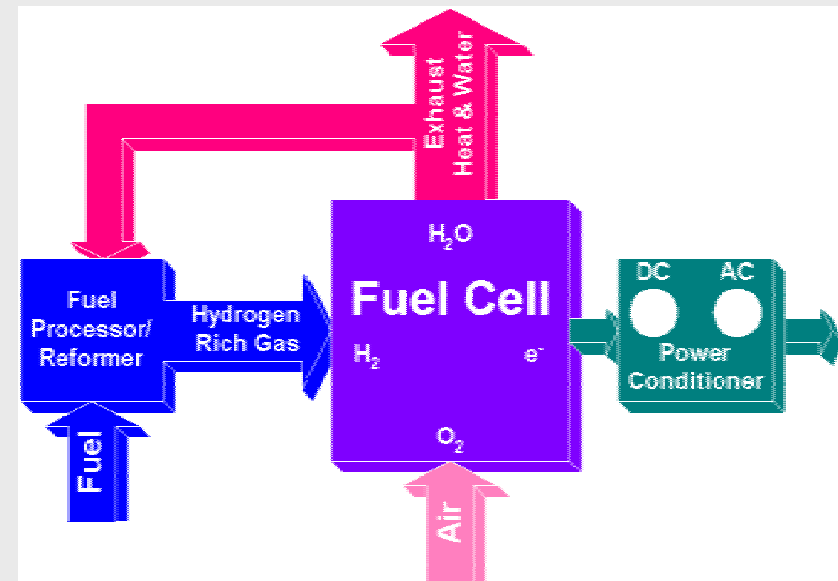
Typical Planar Fuel Cell



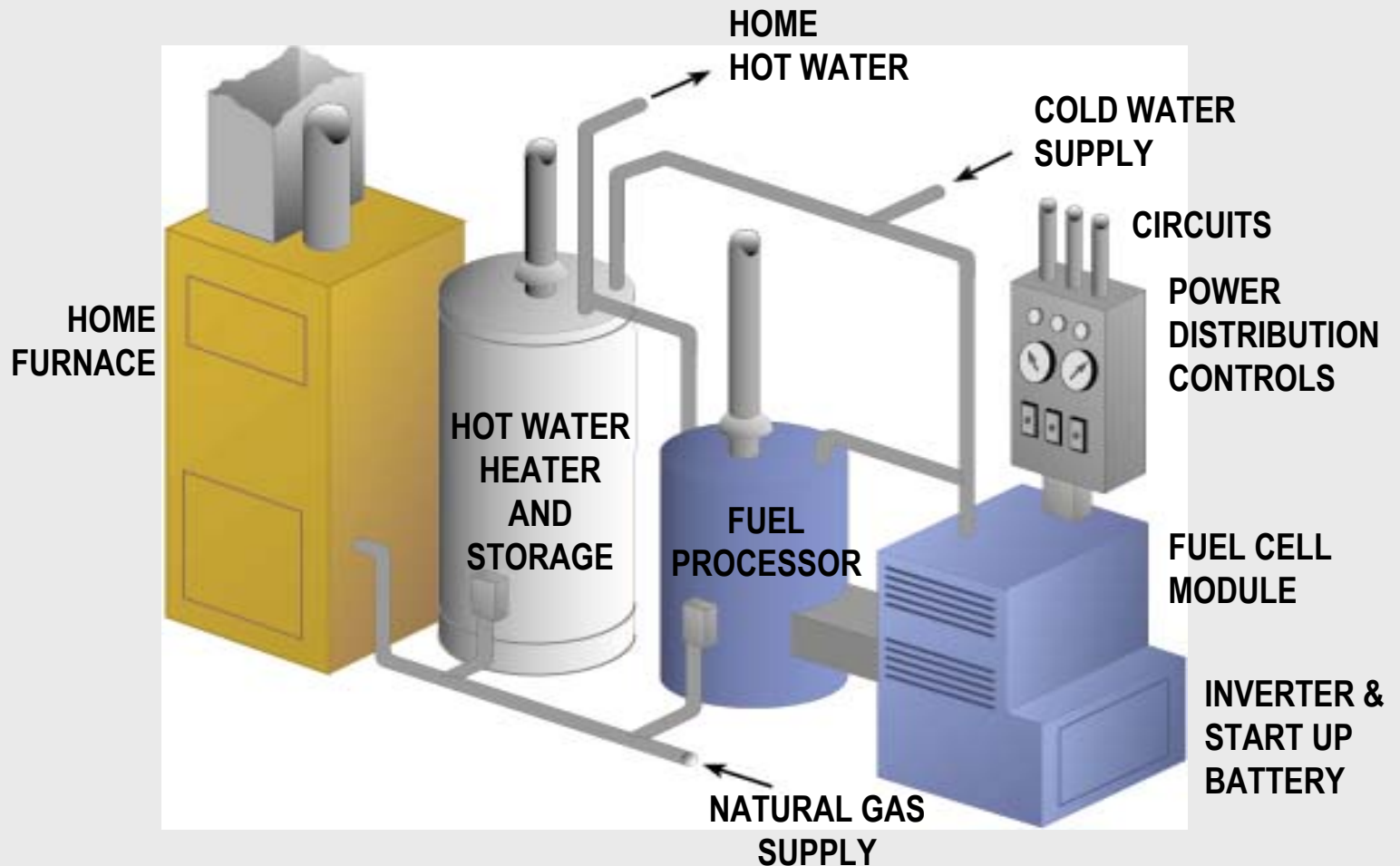
Fuel Cell System

> Practical Fuel Cell Systems:

- Often use hydrocarbon fuels (e.g., natural gas)
- Make (and consume) hydrogen-rich gas through reforming
- Air as oxygen source
- Use many cells to increase voltage/ power (i.e., a “stack”)
- Use integrated heat recovery to improve system efficiency
- Use a DC to AC power conditioner



Conceptual Home Fuel Cell System

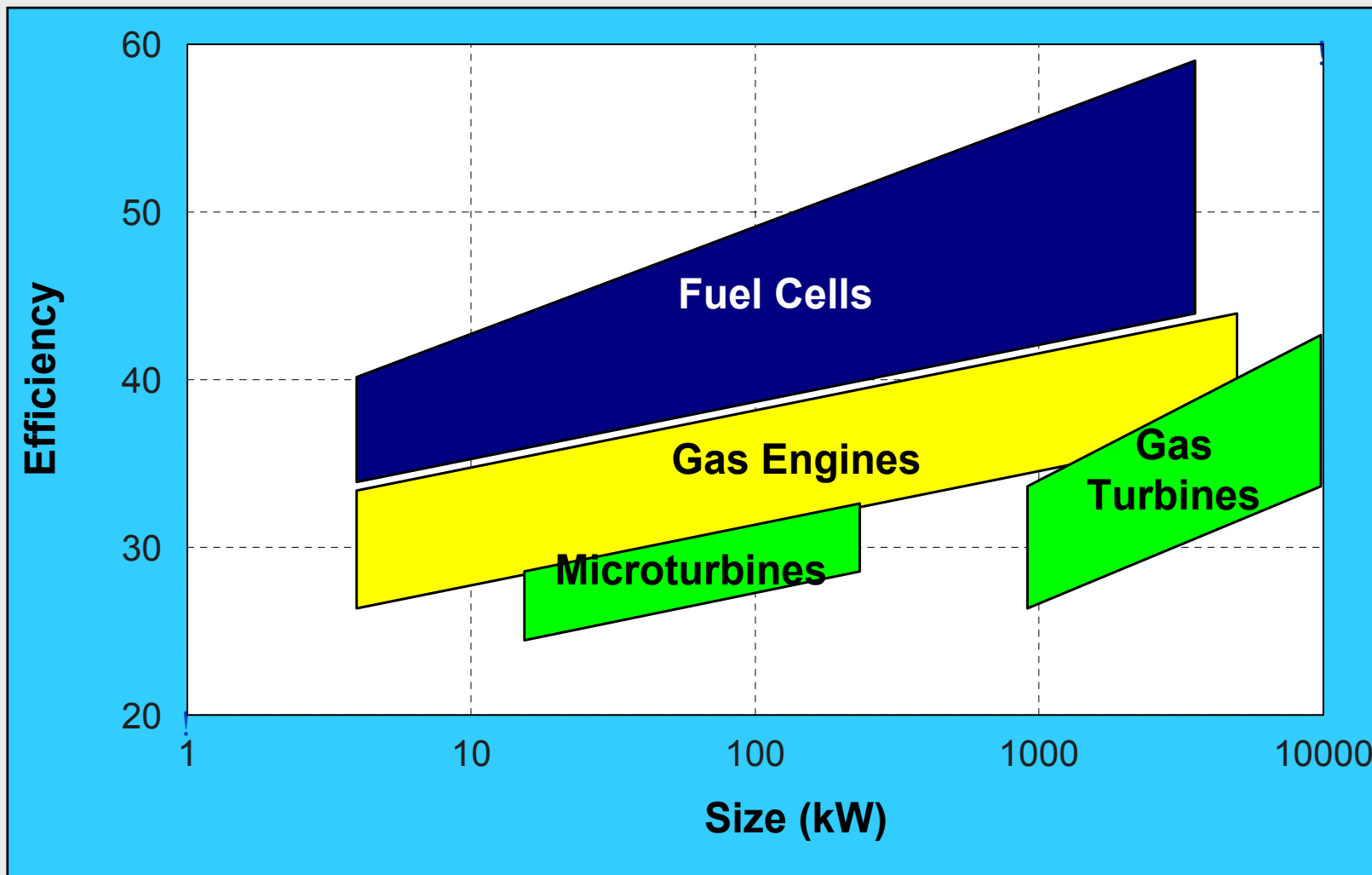


Fuel Cells History & Types

- > 1839: Sir William Grove demonstrates reverse hydrolysis
- > 1940s: Francis Bacon builds first true fuel cell stack
- > 1950s: Alkaline fuel cell first used in space program
- > 1960s to present: used in every manned space program
- > 1991: ONSI PAFC introduced as first commercial stationary fuel cell

- > Four primary technologies in development since the 1960s:
 - Solid Oxide
 - Molten Carbonate
 - Phosphoric Acid
 - Proton Exchange Membrane (PEM)

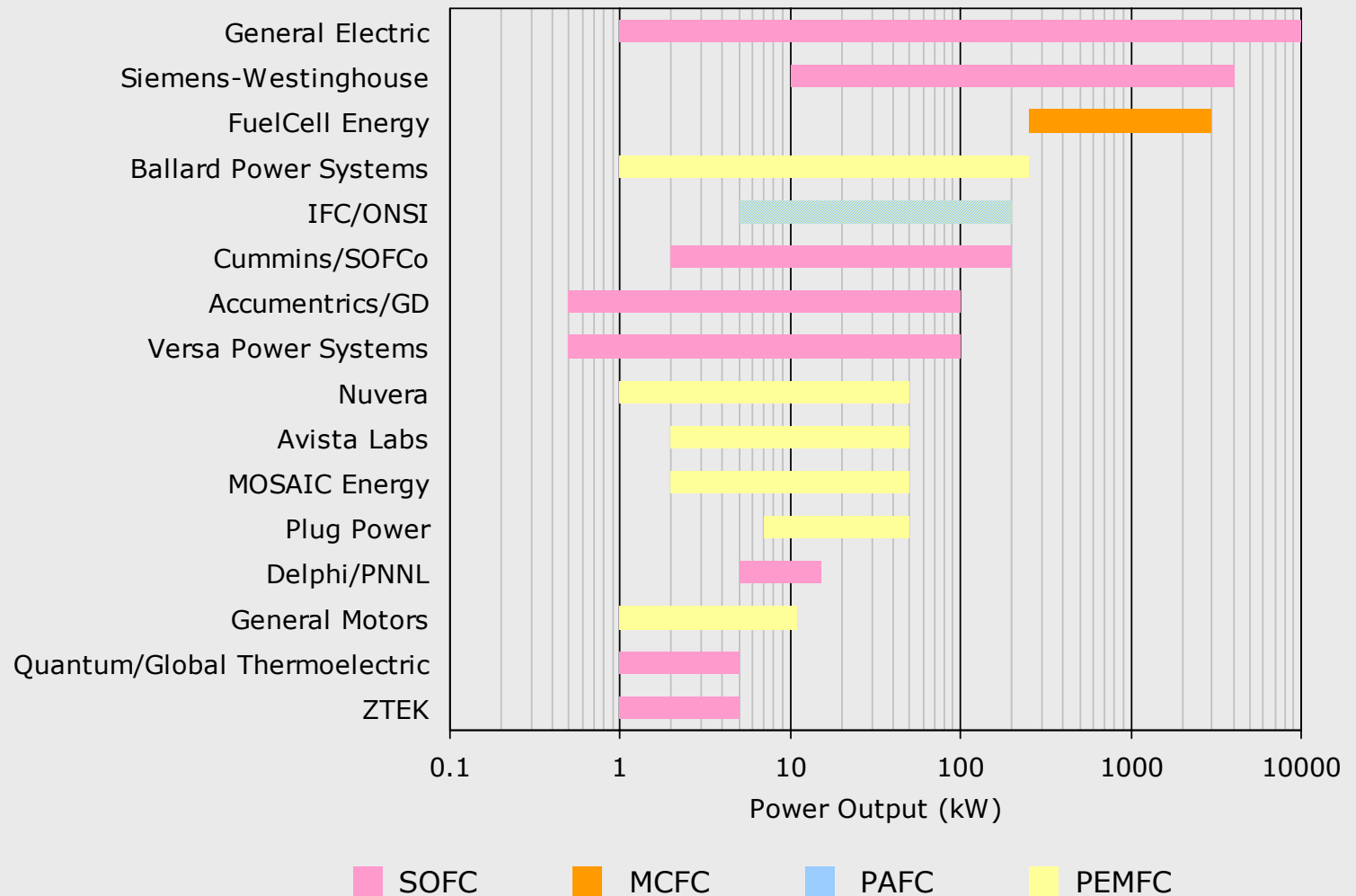
Distributed Generation Product Mix



Fuel Cell Attributes

	PEMFC Proton Exchange Membrane	PAFC Phosphoric Acid	MCFC Molten Carbonate	SOFC Solid Oxide
Electrolyte	Sulfonic acid in polymer	Orthophosphoric acid	Lithium and potassium carbonates	Yttrium-stabilized zirconia
Charge Carrier	H ⁺	H ⁺	CO ₃ ⁼	O ⁼
Operating Temperature	175 F Warm Water	390 F Hot Water	1,200 F High-Pressure Steam	1,300 – 2,000 F High-Pressure Steam
Cogeneration Heat	Minimal	Modest	High	High
Efficiency (LHV)	< 40%	35 - 45%	45 – 60%	45 – 60%
Reforming	External	External	Internal or external	Internal or external

Stationary Fuel Cell Developers



Fuel Cell Technology Hurdles

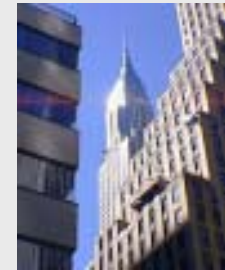
- > Demonstrate reliability in real-world applications
 - “High 9’s” reliability
 - Long mean time between forced outages
- > Increase stack & system life
 - Long mean time between overhaul or replacement
- > Reduce cost & complexity of balance-of-plant equipment

Fuel Cells Have Multiple Applications

Transportation



Stationary Power



Fuel Cells

Grid Support



Portable and Premium Power



Military

Stationary Fuel Cell Applications

- > Fuel cells can be used in many stationary applications
 - Building power
 - > Single family, multi-family, commercial, institutional
 - Communications power
 - > Telephone, wireless, cable systems
 - Industrial (cogeneration)
 - Utility ancillary services
 - > Grid voltage support, operating reserve

Power Generation Classifications

- > Power generation units can be classified into three usage types
 - Baseload
 - > Sizing driven by load duration and implementation
 - Peakshaving
 - > Most useful for higher peak demand customers with time-of-use rates
 - Backup/standby
 - > Need for reliability allows for higher cost per kW units relative to baseload applications

Where Do Fuel Cells Fit?

	<i>Recip. Engines</i>	<i>Micro- turbines</i>	<i>Low-Temp. Fuel Cells</i>	<i>High-Temp. Fuel Cells</i>
Baseload	<input type="checkbox"/>	<input type="radio"/>	<input checked="" type="radio"/>	<input checked="" type="radio"/>
CHP	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="radio"/>
Peaking	<input checked="" type="radio"/>	<input checked="" type="radio"/>	<input type="radio"/>	<input type="radio"/>
Standby/Backup	<input checked="" type="radio"/>	<input checked="" type="radio"/>	<input type="checkbox"/>	<input type="radio"/>
Power Quality	<input type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="radio"/>	<input type="checkbox"/>

Source: ADL

Suitability: Low ☐ — ☒ High

Fuel Cell Benefits

- > High efficiency
- > Reduced grid dependence
- > Improved electrical reliability
- > High quality power
- > Environmentally friendly
 - Often exempt from permitting restrictions
- > Low noise
- > Scalable
- > Useful heat
 - Particularly for SOFC and MCFC

Reliability Benefits

Real, But Often A Challenge To Quantify

- > Power-related problems are estimated to cost U.S. companies \$26 billion a year in lost time and revenue

<i>Industry</i>	<i>Average Cost of Downtime per Hour</i>
Cellular Communications ^a	\$41,000
Telephone Ticket Sales	\$72,000
Airline Reservations	\$90,000
Credit Card Operations	\$2,580,000
Brokerage Operations	\$6,480,000

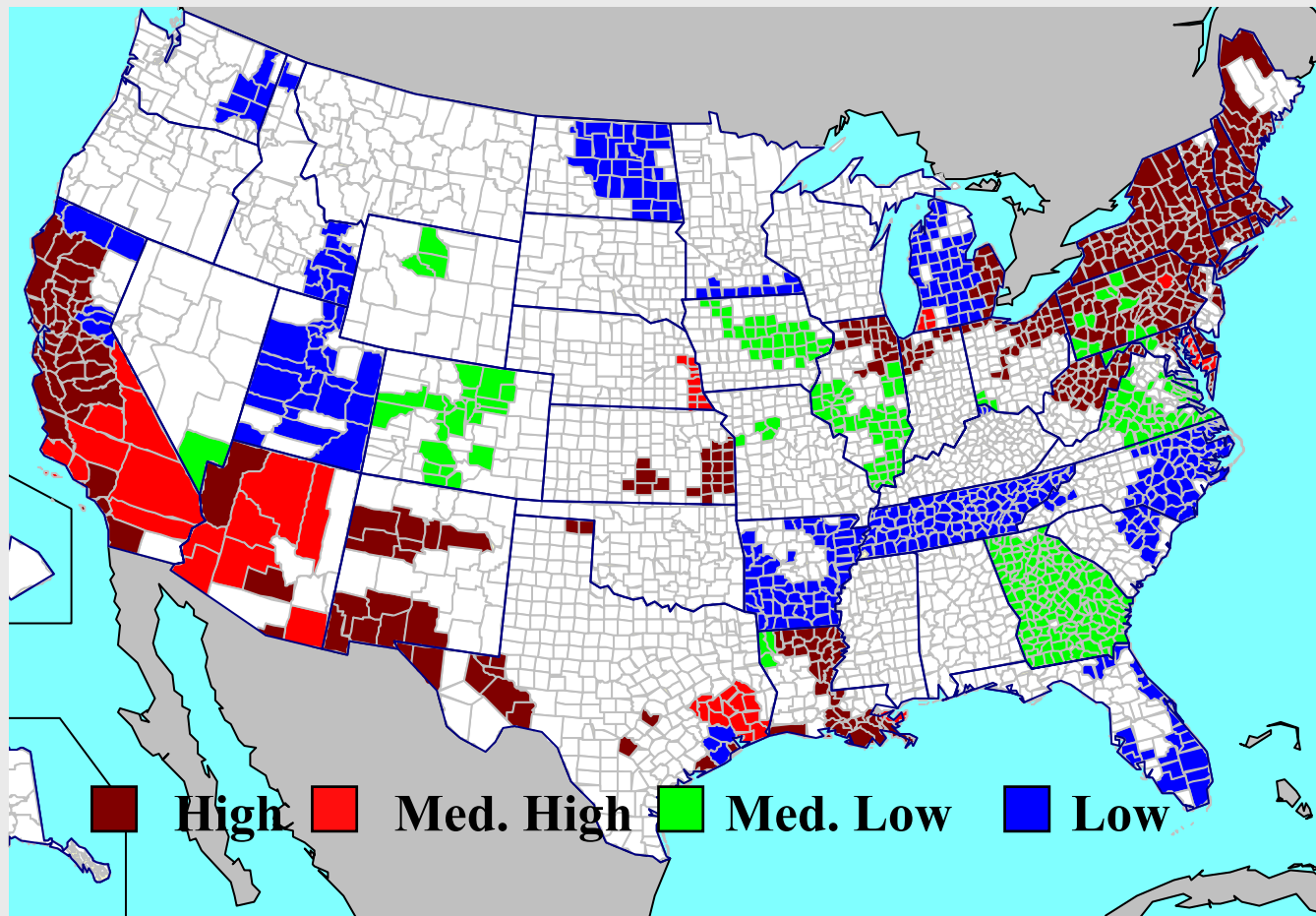
^a Teleconnect Magazine, all others Contingency Planning Research 1996

Market Drivers

- > Electricity supply and demand imbalances
 - Recently, demand increases have outpaced capacity additions
 - Capacity margins have fallen from around 30% in the 1980s to about 15% today
- > Transmission and distribution constraints
 - Pending deregulation creates uncertainty concerning the future disposition of stranded assets
 - Expanding T&D capacity is expensive and slow
- > Air quality in metropolitan areas
 - Fuel Cells represent an ultra-low-emission power source
- > Energy cost savings
 - Demand and energy costs

Market Opportunity

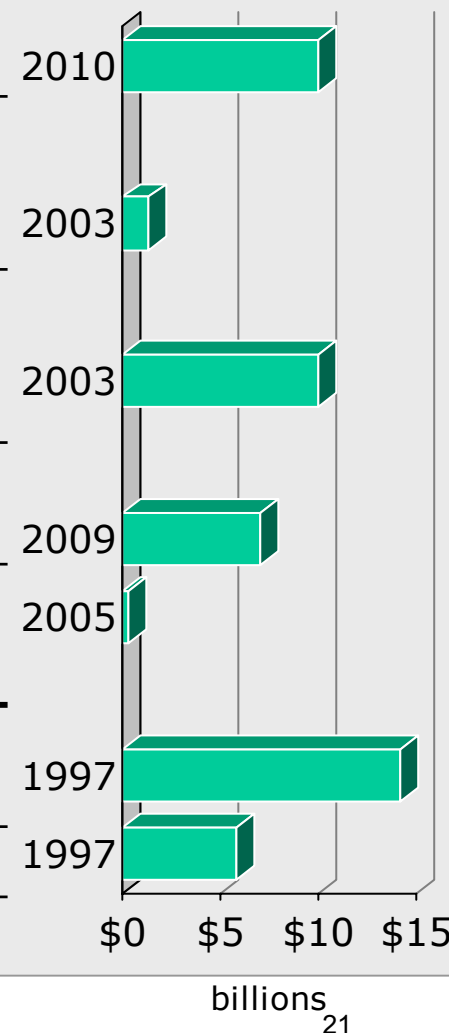
Electric Rates Impact Market Potential



Source: CNG/Columbia

Market Projections

<i>Study Author</i>	<i>Market</i>
Allied Business Intelligence	US and global stationary (50W to 3MW)
Business Communications Company	Includes stationary and automotive
Business Communications Company	Includes stationary and automotive (different study)
Freedonia Group	Fuel cells and related products (incl. auto and portable)
Frost & Sullivan	North American stationary
<i>For Comparison...</i>	
Warm air heating and air conditioning equipment and supplies (SIC 5075)	
Turbines and turbine generator sets (SIC 3511)	



Fuel Cells - Summary

- > Fuel Cells are attractive long-term options for small-scale (under 5 MW) power generation
- > Current stationary fuel cell products are premium priced
 - Over \$3000/kW
 - Niche market option for most market segments
- > Significant ongoing investment for stationary & mobile fuel cells
 - Technologies & products will continue to evolve and mature over coming decade
 - Significant resources targeting PEMFC and SOFC fuel cells

Fuel Cell Codes and Standards

- > Product standards
- > Installation standards
- > Interface/interconnection standards
- > Code coverage/field evaluations
- > Performance standards

Acronym Soup

- > ANSI
 - American National Standards Institute
- > ASME
 - American Society of Mechanical Engineers
- > CSA
 - CSA International
- > ICC
 - International Code Council
- > IEEE
 - Institute of Electrical and Electronics Engineers
- > NFPA
 - National Fire Protection Association
- > UL
 - Underwriters Laboratories

Product Standards

- > ANSI Z21.83-1998, Fuel Cell Power Plants
 - Applies to natural gas or propane systems under 600 VAC and 1000 kW
- > CSA FC 1, Fuel Cell Power Plants
 - Planned replacement for ANSI Z21.83
 - Increases power output limit to 10 MW and encompasses more fuel types
- > CSA U.S. Requirements 1.01, Residential Fuel Cell Power Generators
 - Supplements ANSI Z21.83 for power < 50 kW
- > *Used to certify equipment, not installations*

Installation Standards

- > NFPA 853, Standard for the Installation of Stationary Fuel Cell Power Plants
 - Covers siting, fuel storage, exhaust, and fire protection for units larger than 50 kW
 - Planned revisions will remove the 50 kW limit
- > NFPA 70, National Electrical Code
 - Article 692 (2002) covers electrical installation requirements for fuel cell systems
- > NFPA 54, National Fuel Gas Code
- > NFPA 58, Liquefied Petroleum Gas Code

Electrical Interconnection

- > UL 1741, Standard for Inverters, Converters, and Controllers for use in Independent Power Systems
 - Scope includes both grid connected and grid independent systems, being modified to include fuel cell systems
- > IEEE P1547, Standard for Interconnecting Distributed Resources with Electric Power Systems
 - Draft standard covers grid connection
 - IEEE P1608 is companion Application Guide
- > *These two standards will be harmonized, and the work done in P1547 will be adopted into UL 1741*

Code Coverage

- > ICC Mechanical Code
 - Section 924, Stationary Fuel Cell Power Plants
 - *"Stationary fuel cell power plants having a power output not exceeding 1,000 kW, shall be tested in accordance with ANSI Z21.83 and shall be installed in accordance with the manufacturer's installation instructions."*

Field Evaluation

- > UL 2262, Outline of Investigation on PEM type Fuel Cell Power Plants
 - This is an internal (UL) document developed to help assess PEM fuel cells. It is not a national standard and will not be used once national standards are developed that cover this topic
- > ANSI Z21.83
- > NFPA 70
- > Local Codes
 - Mechanical, Fire, Plumbing, Fuel Gas, etc.

Field Evaluations

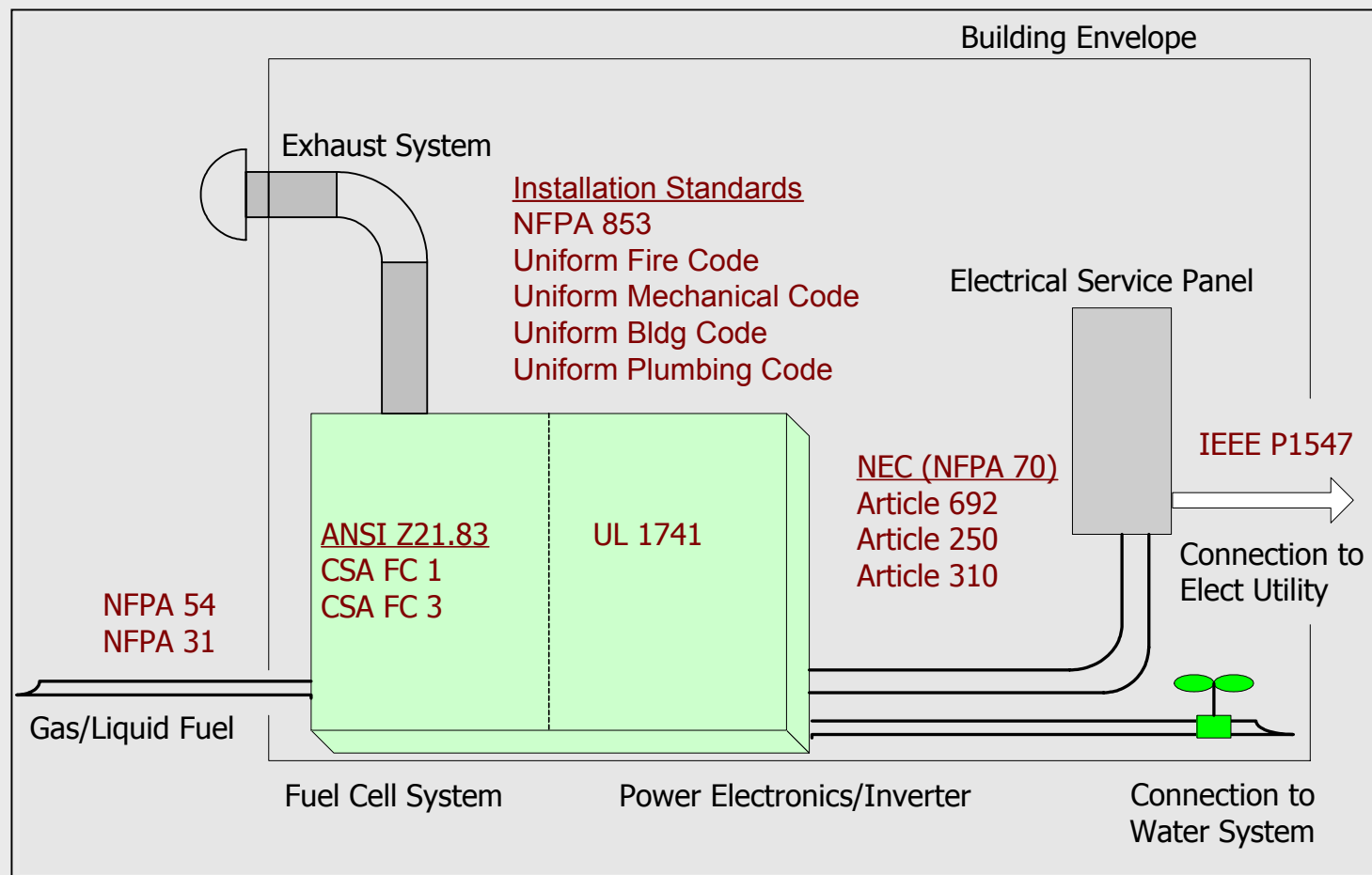
- > Additional considerations
 - “Approved” components
 - Heat rise testing
 - Insulation resistance
 - Dielectric withstand and leakage current tests
 - Ground continuity tests

- > If there is insufficient guidance in Product Standards, National Standards such as NFPA 79, Electrical Standard for Industrial Machinery may be used

Performance Standards

- > CSA CAS No. 33, Component Acceptance Service for PEM Fuel Cell Modules
 - Specifications for PEM fuel cells stacks
- > ASME PTC 50, Performance Test Code for Fuel Cell Power System Performance
 - Covers testing procedures, methods and definitions for assessing the performance characteristics
- > IEEE P1589, Standard for Conformance Test Procedures for Equipment Interconnecting Distributed Resources with Electric Power Systems
 - Specifies the type, production and commissioning tests to demonstrate interconnection functions and that DER equipment conforms to IEEE P1547

Interfaces



For More Information

- > ANSI <http://www.ansi.org/>
- > ASME <http://www.asme.org/>
- > CSA
- > ICC <http://www.intlcode.org/>
- > IEEE
- > NFPA <http://www.nfpa.org/>
- > UL <http://www.ul.com/>

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